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# Optimization and Development of Gluten-free Noodles from Foxtail Millet using Response Surface Methodology

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***Abstract:**The current study is being conducted to optimize the use of Composite flours of Wheat and Foxtail millet, Guar gum through Response Surface Methodology (RSM) to produce gluten-free millet noodles. For the current research, the base materials such as wheat flour (40-80 g), Foxtail millet flour (20-60g) and Guar gum (0.50-1.00 g) assumed as independent variables which are optimized after performing RSM .The following responses are predicted for Gluten content, Glycemic index, cooking loss, cooking time and Sensory traits. 17 Exceptional combinations are generated within the experimental design and are analyzed in order to know the influence of independent variables on responses.The values of processed raw materials such as wheat flour, foxtail millet flour and guar gum are respectively obtained as 60 g, 40 g and 0.75 g.The Gluten content, Glycemic index, cooking loss, Cooking time and sensory characteristics are found 14 g, 49 index, 10 min, 12.6 % and 5, respectively.*

***Keywords:** Foxtail millet flour, Wheat flour, Gluten-free, RSM, Optimisation*

## I. INTRODUCTION

Noodles are one of the popular extruded products largely consumed during the world. Though it is largely fed on the other side many researchers are exploring the capability of noodle fortification as a powerful public health intervention and growth its dietary characteristics. The characteristics like flavour, nutrition, convenience, protection, longer shelf life, and affordable price have made the noodles popular.The quantity of flour utilised for noodle making in Asia debts for about 40% of the total flour fed on. The wheat produced normally belongs to Triticum aestivem (95%), Triticum durum (4%), Triticum dicoccum (1%) species which might be used for bakery, RTE foods and traditional foods. Wheat flour noodles are an essential element within the diet of many Asians and it's miles globally demanded due to the particular viscoelasticity and low gluten in addition to an outstanding array of vitamins such as B1,B2, B3,B5, and B9,which facilitate the production and consumption of processed foods whose intake is growing as a result of the global industrialized westernization technique. The wheat flour offers progressed water absorption and dough managing houses, tenderizing effect and resiliency. They also consequences extra uniform, moother and extra pliable with less sticky nature dough.

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This attempt also includes the millets as it has higher nutritional content. Foxtail millet which is rich in the source of dietary fibre, Phosphorous, manganese, chromium etc. It has been noted that it is good for diabetic because of its low glycemic index. Gluten isgenerally a protein found in refined wheat flour, Barley and Rye. Everyday people consuming food products which are rich in gluten such as pasta, noodles, bread, etc, A good sized quantity of people revel in an destructive reaction to gluten consumption, means that they need to persist with a gluten free eating regimen. The extruded products like noodles are being consumed across the world; hence this type of extruded food has been utilized to enrich it with nutrients as it may have a wide range of reach in the market. To avoid these problems a gluten-free noodles with millets this enriches the properties of extruded foods.

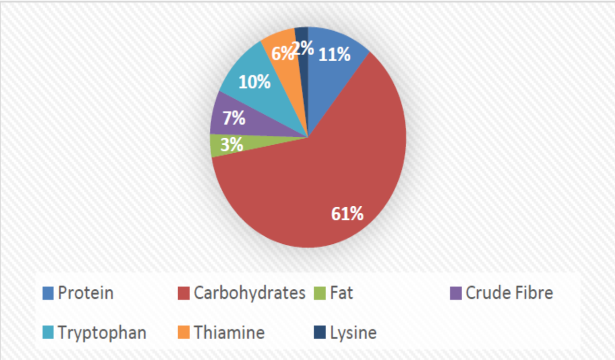


**Figure 1. Nutritive value of Foxtail millet flour Methodology Experimental Layout**

For model the experimental combinations, Response Surface Methodology (RSM) is followed. The main advantage of RSM is that it had to give sufficient records of statistically perfect results to minimize the variety of test runs. For this work, experimental model from Behnken is used. The proportion of wheat flour (40-80 g), Foxtail millet flour (20-60) and Guar gum (0.50-1.00 g) is covered by objective variables. Gluten content, glycemic index, lack of cooking, cooking time and sensory characteristics is the response variables. The ingredients viz. for the production of gluten-free noodles based on millet. Wheat flour, millet flour from Foxtail and guar gum are used. Foxtail millet flour, sathy, wheat flour is prepared just before the experiment. A room temperature of 27$^{o}$C is processed for foxtail millet and wheat flour. The wheat flour particle size is 0.336 mm. The Foxtail millet is soaked for 30 minutes; dried for 1 hour at 60$^{o}$C, then ground in the mill and sieved to the 0.336 mm particle size flour is given in Figure 2.


**Figure2. Process flow for the processing of Foxtail millet grain**

**Processing of Noodles**

Foxtail millet flour
Wheat flour

Blending (5min)

Water

Kneading (45min)

Resting (30 min)

Sheeting

Cutting

Steam cooking (100ºC for 15 minutes)

Dehydrating(65 ºC for 3 hrs )

Packing

**Figure3. Process flow for the Preparation of Noodles**

There is a combination of Foxtail millet flour, Wheat flour and Guar gum. The measurements were made at 25±1$^{o}$C (Table 1).A type of laboratory design extruder prototype used for testing. The ingredients are combined with the most beneficial amount of water for the homogeneous mixing of dough and the dough is prepared. The resulting material is allowed to rest for 1/2 hour at room temperature 22 ± 1oC. The parts of the dough are kneaded to form a dough ball that is flattened with a rolling pin after which the controlling knob set at 2.5 mm hole passes through the rolling device of an extruder. The resulting sheet is folded once in half and then handed three times through the extruder process rolls, allowing an order to give a standard sheet that stays together as a single piece of dough. The sheet thickness is gradually reduced by moving 5 times between the extruder machine rolls with the roll distance gradually reduced to 1.5 mm. These are then equally positioned in a steam pan that is transferred right into a preheated steamer (100 ° C) and steamed for 15 min to allow the starches to swell. The last stage is drying and it is transferred in a drier preheat ed to 65°C to reduce the moisture content to 6.50%. Upon pr eparation, the samples are dried at 60oC for 3 hours to reduc e the product content of the moisture up to 6.50 %.Physio-chemical analysis Wheat flour and Foxtail millet flour are evaluated for water, ash, fat, dietary fibers and sodium. Gluten content and composite flour and noodles glycaemic index are determined. The process of the hot air oven is used to assess the noodle moisture content (AOAC,2016). Ash content of noodles is determined by the standard procedure as outlined in (AOAC,2016), while fat is measured using soxhlet tools as outlined in AOAC (2016-320.85). This defines the process used to assess the sodium (IS 9497:1980 RA 2015) Nutritional fiber is calculated as defined in (IS 10226 element 1) in

**Table 1. RSM data for different trials**

| Runs | Factor 1 A:Wheat flour(g) | Factor 2 B:Foxtail millet flour | Factor 3 C: Guar gum | Response 1 Gluten ppm | Response 2 Glycemic index | Response 3 Cooking time(min) | Response 4 Cooking loss(%) | Response 5 Sensory evaluation |
|---|---|---|---|---|---|---|---|---|
| 1 | 40 | 40 | 0.5 | 13 | 54 | 5 | 12.2 | 3 |
| 2 | 80 | 60 | 0.75 | 22 | 49 | 20 | 10.2 | 9 |
| 3 | 40 | 20 | 0.75 | 14 | 57 | 15 | 12.6 | 9 |
| 4 | 60 | 20 | 1 | 19.5 | 57 | 10 | 11.4 | 7 |
| 5 | 60 | 40 | 0.75 | 19.5 | 54 | 15 | 11.2 | 9 |
| 6 | 60 | 60 | 0.5 | 19.5 | 48 | 5 | 11 | 3 |
| 7 | 60 | 60 | 1 | 19.5 | 50 | 5 | 11.4 | 4 |
| 8 | 60 | 40 | 0.75 | 19.5 | 54 | 15 | 11.2 | 9 |
| 9 | 40 | 40 | 1 | 15 | 54 | 5 | 13 | 4 |
| 10 | 80 | 40 | 1 | 22 | 54 | 20 | 10.6 | 7 |
| 11 | 60 | 40 | 0.75 | 19.5 | 54 | 15 | 11.2 | 9 |
| 12 | 80 | 40 | 0.5 | 22 | 54 | 20 | 9 | 6 |
| 13 | 60 | 40 | 0.75 | 19.5 | 54 | 15 | 11.2 | 9 |
| 14 | 60 | 20 | 0.5 | 19.5 | 57 | 10 | 11 | 6 |
| 15 | 60 | 40 | 0.75 | 19.5 | 54 | 15 | 11.2 | 9 |
| 16 | 80 | 20 | 0.75 | 22 | 57 | 20 | 10.2 | 8 |
| 17 | 40 | 60 | 0.75 | 14 | 49 | 10 | 12.6 | 5 |

accordance with the process. Cooking loss and cooking time of noodles are measured the use of a method evolved via (Ding et al.2016).

**Statistical analysis**

For study the effect of independent variables on measured responses, the statistical analysis of the experimental data is performed. The polynomial formula of the second order is used to test the version's statistical significance. The responses for various experimental conditions (Gluten content, Glycemic index, Cooking loss, Cooking time and sensory characteristics of the noodles) were conducted. Using the quadratic model, the average response was obtained for each parameter. Analysis of the response fit and context of the model was performed. The model's adequacy was evaluated using the F-ratio and determination coefficient ($R2$).

Glycemic index $=+54.00+0.000 * A-4.00* B+0.2 * C+0.000* A^2-1.00* B^2+0.000 * C^2+0.000*A * B+0.000* A * C+0.50 * B * C$ --------→**1**

Where A= Wheat flour, B= Foxtail millet flour, C=Guar gum

**Findings and evaluation**

In addition to the related findings, the results obtained from t he existing research are summarized in the following headings:

**Physiochemical raw material analysis**

The physiochemical analysis of wheat flour, foxtail millet flour and composite flour is presented in Table 4.1. Wheat flour was found to contain 14.1% moisture content, 1.8% ash content, and 7% gluten content. Foxtail millet flour had a moisture content of 12 %, ash content of 3.16 %, and no gluten content was detected. Composite flour had a moisture content of 6.29 %, ash content of 2.71%, and gluten content of 19.5%.

**Table 2. Physiochemical analysis of raw material & sample.**

| S. No | Attributes | Wheat flour | Foxtail millet flour | Noodles |
|---|---|---|---|---|
| 1. | Moisture | 14.1 % | 12 % | 6.29 % |
| 2. | Ash | 1.8 % | 3.16 % | 2.71 % |
| 3. | Gluten | 7 ppm | nil | 19.5 ppm |

**Effect of independent variables on Gluten content**

The wheat flour noodles measured gluten content ranged from 13 ppm to 22 ppm (Table 1). The numerical attributes of gluten content are shown in Table 3. Regression model suitable for gluten content material experimental results indicates that the Model F-value of 216.27 implies a significant representation. There is only a 0.01 percent chance that this outsized "Model F-Value" could happen due to noise. The template game was further demonstrated by the commitment coefficient R2i.e. 0.9964, which means that this model can account for 99.64 percent of the response variance. The R2 Adj was 0.9918. Adeq Precision has become 43.907, implying an appropriate signal. A ratio greater than 4 is optimal, and this formula can then be used to evaluate the design area. The model (Eq. 1) was chosen to represent the variance in gluten content, taking into account all of the above criteria. The quadratic version obtained from the lateral enlargement regression analysis in terms of coded variables levels has changed as follows:

$$\text{Gluten} = +19.50+4.00*A+0.000*B+0.25*C-1.50*A^2+0.000*B^2+0.000*C^2+0.000*A*B-0.50*A*C+0.000*B*C \quad ......(1)$$

From the formula, it is clear that noodle gluten content had a highly significant ($P < 0.0001$) negative linear effect of wheat flour (A) and a positive linear effect of foxtail millet flour (B). There was no important other linear word of guar gum (C) ($P>0.05$). There was no important observation of all quadratic and interaction terms ($P>0.05$). Fig.4 showed the effect on the gluten content of wheat flour and foxtail millet flour noodles. It was observed that both influenced the gluten content from the response surface plot between wheat flour and foxtail millet flour. The response surface plot showed that with increasing wheat flour, the gluten content decreased. The reason may be that wheat flour which is itself a good source of gluten content we decreased the amount of wheat flour to make the noodles gluten free.

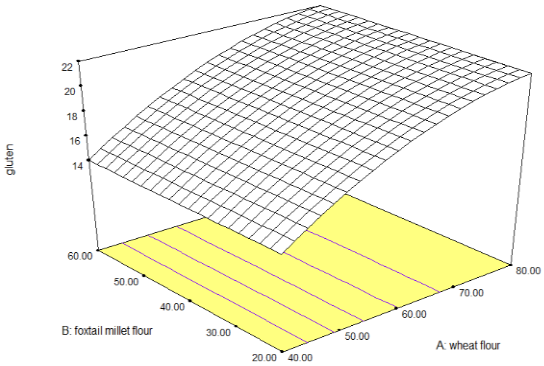


**Fig. 4 Effect of wheat flour and foxtail millet flour on Gluten content**

Effect of independent variables on Glycemic index

The Foxtail millet flour measured glycemic index added noodles ranged from 48 to 57 (Table 1). Table 3 displays the Glycemic index's numerical attributes. Regression model applied to gluten content experimental results shows that the 208.03 Model F-values indicates that the model is relevant. There's only a 0.01 percent chance that this large "Model F-Value" will happen due to noise. The template fit was also demonstrated by the R2i.e determination coefficient. 0.9963, which means that the model can account for 99.63 percent of the response variance. The R2 Adj was 0.9915. The accuracy of Adeq was 43.907, suggesting an effective signal. A ratio of more than 4 is optimal and can therefore be used to traverse the design space. The model (Eq. 2) was selected to represent the variance of the glycemic index, taking into account all the above parameters. The quadratic model obtained in terms of coded variables from regression analysis for lateral expansion was as follows:

$$\text{Glycemic index} = +54.00+0.000*A-4.00*B+0.25*C+0.000*A2-1.00*B2+0.000*C2+0.000*A*B+0.000*A*C+0.50*B*C \quad ......(2)$$

From the formula it is obvious that the noodle glycemic index had a highly significant ($P < 0.0001$) negative linear effect of wheat flour (A) and a positive linear effect of foxtail millet flour (B). There was no important other linear concept of guar gum (C) ($P>0.05$). There was no important observation of all quadratic and interaction terms ($P>0.05$). Fig.5 showed the effect on the gluten content of wheat flour and foxtail millet flour noodles. It was observed from the response surface plot that affected the glycemic index between wheat flour and foxtail millet flour. Response surface plot showed that with rising foxtail millet flour, the glycemic index decreases.

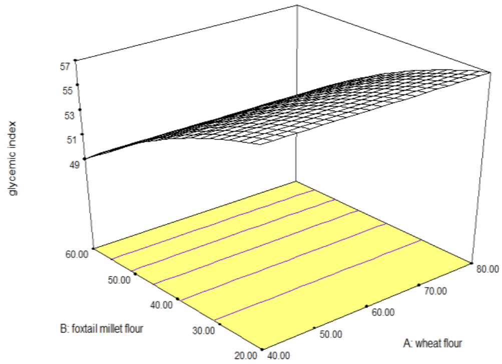


**Fig. 5 Effect of wheat flour and foxtail millet flour on Glycemic index**

**Independent cooking time impact**

The measured cooking time of wheat flour and foxtail millet flour applied to noodles ranged from 5 minutes to 20 minutes (Table 1). Table 3 displays the cooking time numerical attributes. The 11.74 Model F-values implies that the model is important. There's only a 0.19 percent chance that this major "Model F-Value" will happen due to noise. The template fit was also demonstrated by the R2i.e determination coefficient. 0.9379, which indicates that the model could account for 93.79% of the response variability. A ratio of more than 4 is optimal and can therefore be used to traverse the design space. The representation (Eq. 3) was selected to signify the variability in cooking time, taking into account all of the above criteria. The quadratic model obtained from the lateral expansion regression analysis in terms of coded variables.

$$\text{Cooking time} = 15.00+5.63*A-1.88*B+0.000*C+3.13*A^2-1.88*B^2-5.63*C^2+01.25*A*B+0.000*A*C+0.000*B*C \quad ......(3)$$

It is evident from the formula that noodles cooking time had a highly significant ($P < 0.0001$) negative linear effect of wheat flour (A) and a positive linear effect of foxtail millet meal (B). Guar gum (C)was not significant to ($P>0.05$).

The observations of all quadratic and interaction terms (P>0.05) were not significant. Figure 6. Displayed the effect on cooking time of wheat flour and foxtail millet flour noodles. It was observed that both influenced the cooking time from the response surface plot between wheat flour and foxtail millet flour.

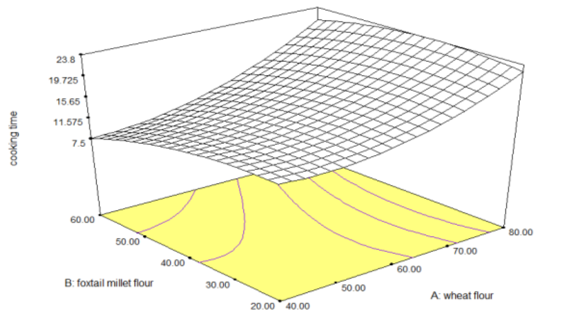


**Fig. 6 Effect of wheat flour and foxtail millets flour on cooking timeIndependent cooking loss impact**

The cooking loss of wheat flour and guar gum added to noodles ranged from 9% to 13% (Table 1). Table 3 displays the cooking loss numerical attributes. The 29.33 Model F-values implies that the model is important. There's only a 0.01 percent chance that this large "Model F-Value" will happen due to noise. The model fit was also demonstrated by the R2 i.e determination coefficient. 0.9742, which means that the model can account for 97.42 %of the response variance. The Adj R2 was 0.9409%. The accuracy of Adeq was 18.545 indicating an adequate signal. A ratio of more than 4 is optimal and can therefore be used to traverse the design space. The model (Eq. 4) was selected to represent the cooking loss variability, taking into account all of the above criteria. The quadratic model obtained in terms of coded variables from the regression analysis for lateral expansion was:

Cooking loss = 11.20-1.30 * A + 0.000 * B+ 0.40 * C +0.100* $A^2$+0.100 * $B^2$ -0.100*$C^2$ +0.000* A * B +0.20 * A * C +0.000* B * C .................................................................... (4)

It is evident from the equation that the cooking loss of noodle had highly significant (P <0.0001) negative linear effect of wheat flour (A) and positive linear effect of foxtail millet flour (B). Other linear term of guar gum (C) was not significant (P> 0.05). All the quadratic and interaction terms were not found significant (P> 0.05). Fig 7. Showed the effect of wheat flour and guar gum noodles on cooking loss. It was observed from the response surface plot between wheat flour and guar gum that when guar gum increases cooking loss increases whereas if wheat flour increases cooking loss decreases.

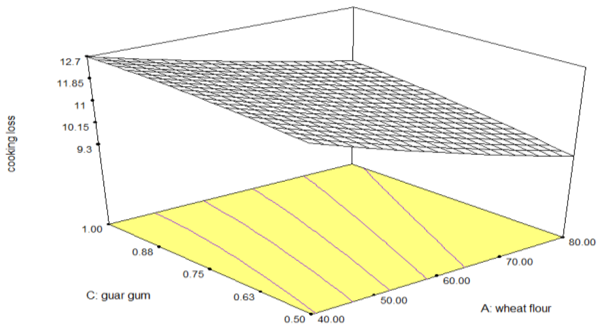


**Fig. 7 Effect of wheat flour and guar gum on cooking lossEffect of independent variables on Sensory evaluation**

The measured sensory evaluation of noodles varied from 2 to 9 (Table 1). Table 3 shows the statistical attributes of sensory evaluation. The Model F -value of 28.42 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. The fit ofmodel was also expressed by the co-efficient ofdetermination $R^2$ *i.e.* 0.9734, which indicates that 97.34%of variability of the response could be explained by themodel. The Adj $R^2$ was 0.9391. Adeq Precision was 12.936 which indicate an adequate signal. A ratio greaterthan 4 is desirable and hence, this model can be used tonavigate the design space. Considering all the above criteria, the model (Eq.5) was selected for representing the variation of cooking time. The quadratic model obtainedfrom regression analysis for lateral expansion in term ofcoded levels of the variables were:

Sensory evaluation = 9.00+1.12*A-1.13 * B+0.50 * C - 0.62 * $A^2$-0.62 * $B^2$ -3.38 *$C^2$ +1.25* A * B +0.000 * A * C +0.000* B * C (5)It is evident from the equation that the cooking time of noodle had highly significant (P <0.0001) negative linear effect of wheat flour (A) and positive linear effect of foxtail millet flour (B). Other linear term of guar gum (C) was not significant (P> 0.05). All the quadratic and interaction terms were not found significant (P> 0.05). Fig 8. Showed the effect of wheat flour and foxtail millet flour noodles on sensory evaluation. It was observed from the response surface plot between wheat flour and foxtail millet flour that when the foxtail millet flour increases the sensory evaluation of the noodles decreases.

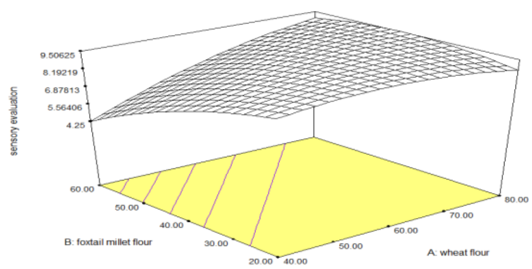


**Fig. 8Effect of wheat flour and foxtail millets flour on sensory evaluation**

**Table 3. ANOVA results of responses as a linear, quadratic and interaction terms on each response**

| Source | Gluten | | Glycemic index | | Cooking time | | Cooking loss | | Sensory evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F-value | p-value | F-value | p-value | F-value | p-value | F-value | p-value | F-value | p-value |
| Model | 216.27 | <0.0001 | 208.03 | <0.0001 | 11.74 | 0.0019 | 29.33 | <0.0001 | 28.42 | 0.0001 |
| A | 1792.00 | <0.0001 | 0.000 | 1.0000 | 56.70 | 0.0001 | 236.60 | <0.0001 | 31.50 | 0.0008 |
| B | 0.000 | 1.0000 | 1792.00 | <0.0001 | 6.30 | 0.0404 | 0.000 | 1.0000 | 31.50 | 0.0008 |
| C | 7.00 | 0.0331 | 7.00 | 0.0331 | 0.000 | 1.0000 | 22.40 | 0.0021 | 6.22 | 0.0413 |
| $A^2$ | 132.63 | <0.0001 | 0.000 | 1.0000 | 9.21 | 0.0190 | 0.74 | 0.4191 | 5.12 | 0.0582 |
| $B^2$ | 0.000 | 1.0000 | 58.95 | 0.0001 | 3.32 | 0.1114 | 0.74 | 0.4191 | 5.12 | 0.0582 |
| $C^2$ | 0.000 | 1.0000 | 0.000 | 1.0000 | 29.84 | 0.0009 | 0.74 | 0.4191 | 149.21 | <0.0001 |
| AB | 0.000 | 1.0000 | 0.000 | 1.0000 | 1.40 | 0.2753 | 0.000 | 1.0000 | 19.44 | 0.0031 |
| AC | 14.00 | 0.0072 | 0.000 | 1.0000 | 0.000 | 1.0000 | 2.80 | 0.1382 | 0.000 | 1.0000 |
| BC | 0.000 | 1.0000 | 14.00 | 0.0072 | 0.000 | 1.0000 | 0.000 | 1.0000 | 0.000 | 1.0000 |
| $R^2$ | 0.9964 | | 0.9963 | | 0.9379 | | 0.9742 | | 0.9734 | |
| Adj $R^2$ | 0.9918 | | 0.9915 | | 0.8580 | | 0.9409 | | 0.9391 | |
| Adeq precision | 43.907 | | 43.907 | | 10.413 | | 18.545 | | 12.936 | |

## II. OPTIMIZATION

Numerical multi-reaction optimization approaches become implemented to decide the most efficient situation of wheat flour, foxtail millet flour and guar gum (Table 3). The optimum ingredients for development of millet based gluten-free noodles were 60.91g of wheat flour, 34.92 g of foxtail millet flour and 0.71 g of guar gum. The predicted values of responses obtained by design expert software resulted of54.9glycemic index,19.6 ppmof gluten, 11 % of cooking loss, 15 minutes of cooking time, 9 of sensory score and the actual values of these response were less than 55glycaemic index, less than 20 ppmgluten, 15% of cooking loss, 20 minutes of cooking time, of sensory scorerespectively (Table 4).

**Table 4. Selection of levels of constraints for optimized condition of noodles**

| Constraints | Goal |
|---|---|
| Wheat flour | Is in range |
| Foxtail millet flour | Is in range |
| Guar gum | Is in range |
| Gluten content | Is in range |
| Glycaemic index | Is in range |
| Cooking time | Is in range |
| Cooking loss | Is in range |
| Sensory score | Maximize |

**Table 5. Predicted and actual values of responses**

| Responses | Predicted value | Actual value |
|---|---|---|
| Gluten content | 19.6 ppm | 20 ppm |
| Glycaemic index | 54.9 | < 55 |
| Cooking time | 15 min | < 20 min |
| Cooking loss | 11 % | 15 % |
| Sensory score | 9 | 9 |

## III. CONCLUSION

From the proceeding discussions and evaluation of outcomes, it may be summed up that components especially wheat flour level prompted tremendous effects on noodles. The outcome of the present studies may be used as valuable information for the improvement of millet primarily based gluten-loose noodles. Noodle samples have been formulated from one of a kind combination of wheat flour, foxtail millet flour and guar gum. The gluten and glycemic index of the noodles varied because of variant in level of wheat flour incorporation and chemical changes. The general consequences screen that the texture and flavour of noodles became ideal whilst stage of incorporation wheat flour changed into accelerated as much as 60%. It became observed that cooking loss and cooking time multiplied with the growth in wheat flour proportion, while dietary fibre, sodium and glycemic index decrease with the growth in foxtail millet flour ratio.

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